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Can measures of social cognition predict autistic traits?

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ABSTRACT

Past research has yielded conflicting findings concerning socio-cognitive deficits in individuals with autistic traits. This raises the fundamental question whether autistic traits and socio-cognitive abilities are related. The present study investigated whether three key socio-cognitive abilities—imitation-inhibition, empathy, and emotion regulation—can serve as predictive factors for autistic traits within a neurotypical population. Participants ($N = 166$, $M_{age} = 24.83$ years, $SD_{age} = 5.20$ years, $range_{age} = 18$ to 39 years) were asked to perform an online imitation-inhibition task and complete self-report measures assessing empathy, emotion regulation, and autistic traits. Empathy was measured using the Interpersonal Reactivity Index (IRI), emotion regulation was assessed using the Difficulties in Emotion Regulation Scale (DERS), and autistic traits were measured using the ten-item short form of the Autism-Spectrum Quotient (AQ-10). Multiple regression analyses revealed that both imitation-inhibition and emotion regulation were significantly associated with autistic traits. However, empathy was not found to be a significant predictor. Our study aimed to clarify inconsistent results regarding the relationship between socio-cognitive abilities and autistic traits.

1. Introduction

Autism is a common neurodevelopmental disorder that impacts an individual's ability to communicate and interact with others. It is often marked by social communication difficulties, repetitive behaviors, and restricted interests (American Psychiatric Association, 2013). Currently, the etiology of autism is not clear. The "broken mirror" theory of autism (Williams et al., 2001) states that a dysfunction of the mirror neuron system (MNS) can result in impairments to imitate other, which in turns may give rise to autism (Oberman et al., 2005; Williams, 2008; Williams et al., 2001). There has been a longstanding debate about the extent to which individuals with autism have issues imitating or inhibiting imitative responses. Some studies show that people with autism present hypo-imitation (i.e., a reduced ability to imitate) and this seems to be linked to impairments in the MNS (Williams et al., 2001). On the other hand, there are also reports of hyper-imitation (i.e., excessive imitation) in people with autism, which has been theorized to result from a reduced imitation-inhibition ability (Brass et al., 2009; Spengler et al., 2010). Overall, while some studies argue that autism may be caused by impaired MNS functioning, other studies have failed to replicate any MNS impairments in autism (see Yates & Hobson, 2020, for a review).

In order to study imitation some studies have used the imitation-inhibition paradigm (Brass et al., 2000; Cracco et al., 2018). In this task, participants are required to move their fingers to respond to a target while simultaneously observing finger movements. The key index measured in this task is thought to reflect an individual's ability to inhibit imitation (Santiesteban, Banissy et al., 2012). Imitation-inhibition is the ability to inhibit the tendency to automatically imitate another's action; which in turn requires the enhancement of mental representations of the self while inhibiting representations of the other (Brass et al., 2009; Santiesteban, White et al., 2012). A fundamental mechanism underlying imitation inhibition is the ability to distinguish and control between self and other representations, known as self-other distinction (SOD; Brass et al., 2009). The self-other control theory (Brass et al., 2009; Spengler et al., 2009, 2010) suggests that individuals with autism exhibit faulty SOD processes, which can contribute to various social and cognitive difficulties. The SOD mechanism has been extensively studied in three main domains: the motor domain, the affective domain, and the socio-cognitive domain. At the motor level, in order to inhibit automatic imitation, individuals are required to differentiate between their own internally generated motor representations and those generated when observing other people's

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actions (Brass et al., 2009; Santiesteban, White et al., 2012). There is evidence that imitation-inhibition is relatively spared in autism (e.g., Sowden et al., 2016) and that imitation-inhibition difficulties depend on specific contexts (Cook & Bird, 2012; Cracco et al., 2018; Wang & Hamilton, 2012). For instance, Cook and Bird (2012) found that individuals with autism do not show increased imitation to pro-social stimulus primes as neurotypical people do.

In the context of the affective domain, specifically in empathy —the ability to identify and respond to the emotions of others — we are required to distinguish between our own emotions and those of others (Iacoboni, 2009). Moreover, it has been suggested that when we observe negative emotions in others, we need to differentiate between our own affective state and that of the other person (Lamm et al., 2016). Therefore, SOD may reduce the personal stress involved in understanding these emotions. Recent research suggests that individuals with autism may have difficulties with cognitive empathy, i.e., the ability to understand the thoughts and feelings of others, but may be able to experience affective empathy, i.e., the ability to feel and share the emotions of others (aan het Rot & Hogenelst, 2014; Mazza et al., 2014; see also, Dziobek et al., 2008; Rueda et al., 2015). However, other studies have shown that individuals with autism may actually have heightened empathy (Markram, 2007; Smith, 2009). Furthermore, it has been shown that individuals with autism are motivated to help others with autism (Komeda et al., 2019) and do not lack empathy per se (Santiesteban et al., 2021). These studies suggest that individuals with autism may have impairments in cognitive empathy but are still able to experience affective empathy.

Another domain in which SOD has been studied is the socio-cognitive domain, where SOD refers to the ability to distinguish one's beliefs, knowledge, and emotions from those of others (Happé et al., 2017). Therefore, SOD is believed to form the foundation for recognizing and managing emotions (Shaw et al., 2020). The term "emotion regulation" refers to the ability of people to manage and express emotions in a way that is appropriate for a given situation (Gross, 2015). It has been shown that difficulties in emotion regulation are linked to core symptoms of autism (Berkovits et al., 2017). Restricted and repetitive behaviors, interests, and activities have been shown to be strong predictors of the association between emotion regulation and symptoms of autism (Samson et al., 2014). Even after controlling for differences in emotional experiences and alexithymia (i.e., the difficulty in identifying and describing emotions; Sifneos, 1973), this atypical pattern of emotion regulation in people with autism persists (Samson et al., 2012). Additionally, individuals with autism may struggle to use coping strategies to manage their emotions effectively (Mazefsky et al., 2013). This can lead to challenges in social interactions and in managing everyday life tasks.

Altogether, there are inconsistent results regarding socio-cognitive functioning in individuals with autism. This inconsistency may be related to the complexity of autism and the comorbidity with other conditions (Buck et al., 2014). One way to overcome this problem is to investigate individuals with autistic traits or what has been called the Broad Autism Phenotype (BAP). The BAP is characterized by traits similar to autism but without a formal autism diagnosis (Bailey et al., 1995; Piven & Palmer, 1999). Prior research has primarily focused on the social interaction deficits in the BAP group. The relationship between BAP level and social interaction impairments has been found to be influenced by social cognition (Sasson et al., 2013). Therefore, autistic traits have been linked to a decreased tendency for spontaneous automatic imitation of social stimuli (Haffey et al., 2013; Sims et al., 2012). Additionally, it has been demonstrated that autistic traits observed in the general population are etiologically associated with autistic traits in individuals diagnosed with autism (Lundström et al., 2012). Overall, studying autistic traits allow us to gain insights into the mechanisms associated with autism.

The purpose of the current study is to examine the relationship between autistic traits and socio-cognitive abilities (imitation-inhibition, empathy, and emotion regulation) in a large sample of participants recruited online. Previous research on the link between imitation-inhibition, autism, and empathy has produced mixed results (Cracco et al., 2018) and needs to be further examined. We hypothesize that greater levels of autistic traits will be associated with decreased abilities to distinguish the self from the other. This is, we predict that individuals with higher levels of autistic traits will exhibit increased levels of congruency effects (slower reaction times and/or more errors on the incongruent trials compared to the congruent trials in the imitation-inhibition paradigm, e.g., Spengler et al., 2010; Trilla et al., 2020). In line with previous findings, we also expect that these individuals will experience higher levels of personal distress (Smith, 2009) and display a higher affective rather than cognitive empathy (Shalev et al., 2022). Furthermore, we predict that higher autistic traits will be related to higher difficulties in emotion regulation (Mazefsky et al., 2013). This study aims to investigate the potential influence of the combination of emotion regulation and imitation-inhibition on autistic traits, which has not yet been explored. Through this investigation, we hope to gain a deeper understanding of social-cognitive functioning in individuals with and without autistic traits.

2. Materials & methods

2.1. Participants

Our sample consisted of 166 adults (116 F, $range_{age} = 18$ to 39 years, $M_{age} = 24.83$ years, $SD_{age} = 5.20$ years). Participants were recruited online through advertisements in relevant social media groups on Facebook and Instagram. Specifically, only individuals residing in Chile were invited to participate in the study. Individuals who expressed interest in participating in the study were instructed to send an email to the designated study email address. Then, a research assistant reached out to these potential participants via phone. During the phone call, the research assistant carefully explained the inclusion and exclusion criteria of the study, ensuring that the individuals fully comprehended the requirements. The inclusion criteria for the study were: (1) being between the ages of 18 and 40 years old, (2) having a normal vision or corrected-to-normal vision, and (3) not having a current diagnosis of a psychiatric or neurological disorder. All participants enrolled in this study were fluent in Spanish. According to the G*Power 3.1 software (Faul et al., 2007; Faul et al., 2009), a sample size of $N = 84$ would be sufficient to detect a correlation of $r = 0.3$ (a medium effect size) with an alpha level of 0.05 and a power of 0.80. The proposed sample size for the present study ($N = 166$) was therefore considered adequate to achieve the main objective of the study. All participants provided written informed consent. This study was approved by the Ethics Committee of the University of Talca (30-2021).

2.2. Questionnaires

Autistic traits were measured using the ten-item short form of the Autism-Spectrum Quotient (AQ-10; López, 2020). The AQ-10 is a brief self-report measure of autistic traits. It consists of 10 items that are based on the Autism Quotient (AQ; Baron-Cohen et al., 2001), which is a lengthy measure of autistic traits. The AQ-10 assesses autistic traits in the areas of social skills, attention to detail, communication, imagination, and daily living. Each item is rated on a 4-point scale with higher scores indicating a greater presence of autistic traits. The AQ-10 has been found to be a reliable and valid measure of autistic traits and has been used in a variety of research studies. It is often used as a screening tool to identify individuals who may be on the autism spectrum or who may have high levels of autistic traits. The internal consistency of the Spanish version of the AQ-Short is reliable (α = 0.60; López, 2020).

Empathy was measured using the Interpersonal Reactivity Index (IRI; Davis, 1983). The IRI is a self-report measure that assesses individual differences in empathy. The IRI consists of 28 items that assess four dimensions of empathy: perspective-taking (PT), fantasy (FS), empathic concern (EC), and personal distress (PD). PT refers to the ability to take the perspective of others and understand their thoughts and feelings. FS refers to the tendency of individuals to immerse themselves imaginatively in the emotions and actions of fictional characters from books, movies, and plays. EC refers to the tendency to feel concern and compassion for others' well-being. Finally, PD refers to the tendency to feel distressed in response to others' negative emotions. The IRI is widely used in research and has been found to be a reliable and valid measure of empathy. The internal consistency of the IRI is good ($\alpha >$ 0.70 in all IRI's subscales; Fernández et al., 2011).

Emotion regulation was measured using the Difficulties in Emotion Regulation Scale (DERS; Gratz & Roemer, 2008). DERS is a measure of emotional dysregulation in adults. It has been translated into Spanish and validated for use with adults in Chile (Guzmán-González et al., 2014). The DERS is a 25-item self-report measure that assesses six dimensions of emotion regulation: awareness of emotions, clarity of emotions, tolerance of distress, ability to refocus attention, acceptance of emotions, and regulation of emotions. The DERS has been found to be a reliable and valid measure of emotion dysregulation in adults in Chile. It has been widely used in research studies and has been found to have strong predictive validity for a range of mental health and well-being outcomes. The internal consistency of the Chilean version of the DERS is very reliable ($\alpha = 0.92$; Guzmán-González et al., 2014).

The Depression Anxiety Stress Scales (DASS; Lovibond & Lovibond, 1995) is a measure of psychological distress that assesses three dimensions: depression, anxiety, and stress. The DASS 21 is a shortened version of the DASS that includes 21 items, with 7 items for each dimension. The DASS 21 is a self-report measure that asks individuals to rate the frequency and severity of various negative emotional and cognitive states over the past week. The DASS 21 has been found to be a reliable and valid measure of psychological distress and has been widely used in research studies. It has been validated for use with a variety of different populations, including adults, children, and older adults. The DASS 21 has also been translated into many different languages and has been validated for use in a range of international settings. The internal consistency of the Chilean version of the DASS-21 is reliable ($\alpha > 0.70$ in all DASS' subscales; Antúnez & Vinet, 2012).

2.3. Procedure

The entire online study was programmed using the jsPsych library (version 6.1.0) and ad-hoc plugins (Westfal et al., 2021) using a JavaScript framework for creating behavioral experiments (de Leeuw, 2015). The experiment was hosted on the online platform Cognition.run (https://www.cognition.run/). In this study, participants were given the opportunity to provide informed consent and were informed that their participation was voluntary. All responses were anonymously processed and stored. To prevent monotony for participants, we mixed questionnaires and paradigms. To avoid fatigue effects, we placed short questionnaires at the end. Participants first completed a series of demographic questions and then moved on to the IRI and DERS questionnaires. Once these were completed, participants completed the imitation-inhibition paradigm (Brass et al., 2000; Brass et al., 2001, b). At the start of each trial, a message appeared instructing the participant to hold down the “G” and “H” keys on a keyboard using their right index and middle fingers (see Fig. 1). Once the participant had placed their fingers, the task began. Each trial started with a fixation cross, which appeared in the center of the screen for 1–1.5 s, followed by an image of a hand in a resting position for 1 s. This was followed by the simultaneous presentation of a number (either 1 or 2) between the two fingers and the lifting of one of the observed fingers (either the index or middle finger). Participants were instructed to lift their index finger for a 1 and their middle finger for a 2. The image remained on the screen until the participant responded or for 1.4 s, whichever occurred first. Finally, after a variable inter-trial interval (ITI) of 1–2 s, the next trial began. The observed finger movements may either match (congruent trials) or mismatch (incongruent trials) the instructed finger movements. There was also a “neutral” condition in which a number was displayed but no finger movement occurred. The observed hands were rotated relative to the surface to eliminate the effects of spatial orientation. There was a total of 240 randomized trials, with 80 trials in each condition (congruent, incongruent, and neutral). To analyze the data, we followed the procedures outlined by Westfal et al. (2021) and removed extremely slow and fast RTs. Specifically, we removed RTs that were >3 standard deviations below or above the participant's mean. Additionally, we eliminated trials with RTs shorter than 100 milliseconds and removed any erroneous trials. Finally, participants completed the DASS-21 and AQ-10 scales before being dismissed.

2.4. Data analysis

We initially examined descriptive statistics to understand variable distributions and assessed multicollinearity using the variance inflation factor (VIF) in addition to a correlation matrix. We computed Pearson correlations when the data were normally distributed (as determined by the Shapiro-Wilk test) and using Kendall's tau when the data were not normally distributed. Subsequently, we employed a multiple regression analysis to examine the predictive relationship between autistic traits, as measured by AQ-10 scores, and various socio-cognitive abilities. In particular, we utilized the backward elimination method to perform this multiple regression analysis, guided by theoretical considerations, and selecting pertinent independent variables, namely imitation-Inhibition, empathy, emotion regulation, age, and sex. The model's construction involved assessing model fit via R-squared and adjusted R-squared values and determining model significance through the F-test. Beta coefficients were scrutinized for relationship strength and direction, with

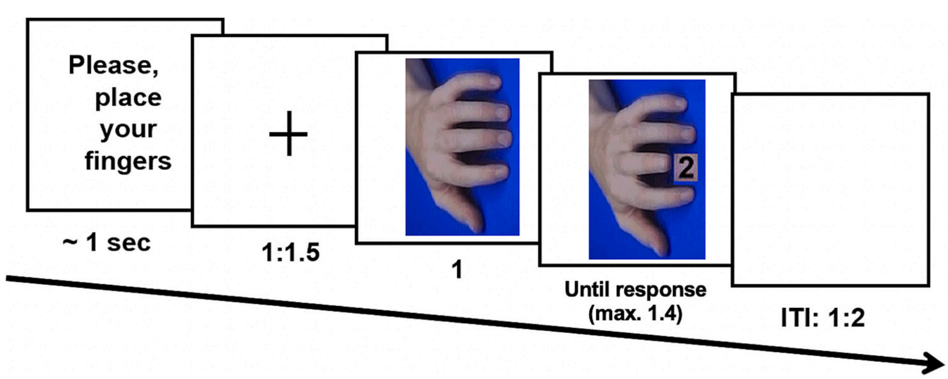

Fig. 1. Timeline of a trial from the Imitation-inhibition paradigm (Brass et al., 2000). Participants were instructed to lift their index or middle finger in response to a number cue while simultaneously observing either a congruent or an incongruent finger movement of a mirrored right hand. The size of the number is smaller in the real experiment. ITI: inter-trial interval.

associated *p*-values indicating significance. Lastly, we validated the model's robustness and generalizability using bootstrapping. These analyses allowed us to examine the unique contribution of each socio-cognitive variable on autistic traits.

3. Results

3.1. Imitation-inhibition

Consistent with previous findings, we observed that participants responded faster during congruent trials ($M = 487.25$ ms, $SD = 83.39$) compared to incongruent trials ($M = 519.44$ ms, $SD = 93.02$), $t(165) = 12.69$, $p < 0.001$, $dz = 0.99$, 95 % CI [0.80, 1.17] (see Fig. 2a). The results for the proportion of errors (PE) of imitation-inhibition were in line with the RTs. We observed that participants made fewer errors in congruent trials ($M = 3.15$ %, $SD = 3.47$) than in incongruent trials ($M = 3.29$ %, $SD = 3.01$), $t(165) = 7.94$, $p < 0.001$, $dz = 0.62$, 95 % CI [0.45, 0.78] (see Fig. 2b). We also combined RT and PE data to compute an inverse efficiency (IE) score. The IE is calculated as the RT divided by the proportion of correct trials [RT/(1-PE)] (Bruyer & Brysbaert, 2011; see also Hogeveen & Obhi, 2013]. IE is expressed in ms. We observed that participants showed lower IE in congruent trials ($M = 503.60$ ms, $SD = 87.93$) than in incongruent trials ($M = 552.42$ ms, $SD = 101.67$), $t(165) = 11.90$, $p < 0.001$, $dz = 0.92$, 95 % CI [0.80, 1.17] (see Fig. 2c). According to previous studies, we decided to focus on the composite IE measure for the subsequent analysis because RT and PE showed a similar pattern of effects (Bruyer & Brysbaert, 2011).

3.2. Correlations

Descriptive statistics and correlations between the applied psychometric measures are presented in Table 1. A Shapiro–Wilk test for multivariate normality was performed and showed evidence of non-normality ($W = 0.917$, $p < 0.001$). Therefore, Kendall's tau was used. The result showed that autistic traits (AQ-10 scores) were negatively correlated with imitation inhibition (the congruency effect) in terms of IE (*tau* = −0.12, $p = 0.03$). Furthermore, AQ-10 scores were positively correlated with difficulties in emotion regulation (DERS total score; *tau* = 0.16, $p < 0.01$), personal distress (IRI PD scores; *tau* = 0.13, $p = 0.02$) and stress levels (DASS stress score; *tau* = 0.13, $p = 0.02$). Finally, we found no correlation between AQ scores and the following IRI subscales: empathic concern subscale, (IRI EC scores; *tau* = −0.01, $p = 0.83$), perspective-taking subscale (IRI PT scores; *tau* = −0.01, $p = 0.86$) and fantasy subscale (IRI FS scores; *tau* = 0.04, $p = 0.50$).

3.3. Multiple regression

A multiple regression using the backward elimination method was conducted to predict AQ-10 scores from imitation-inhibition, empathy, and difficulties in emotion regulation. Additionally, we included age and biological sex as additional predictors in the model (see Supplemental Materials for full model information). The data was screened for linearity, normality and homoscedasticity assumptions and outliers. All assumptions were met, and no outliers were found. In addition, tests for multicollinearity indicated that a very low level of multicollinearity was present (*VIF* = 1.04 for Congruency Effect IE, 1.23 for IRI EC scores, 1.19 for IRI PT scores, 1.76 for IRI PD scores, 1.79 for DERS total scores, 1.17 for age, and 1.08 for biological sex). After the backward elimination process, the variables that remained in the final model were imitation-inhibition (Congruency Effect IE) and difficulties in emotion regulation (DERS total). Congruency Effect IE negatively predicted AQ-10 scores ($\beta = -0.17$, $t(162) = -2.25$, $p = 0.03$) and DERS total score positively predicted AQ-10 scores ($\beta = 0.25$, $t(162) = 3.25$, $p < 0.01$). The multiple regression model statistically significantly predicted AQ-10 scores, $F(3,162) = 6.96$, $p < 0.01$, $R = 0.28$, $R^2 = 0.08$, $R^2_{adjusted} = 0.07$. The bootstrap analysis, involving 1000 iterations of the regression analysis using samples generated through a random replacement procedure, offers substantial evidence regarding the stability and robustness of the coefficient estimates in our regression model (see Supplemental Materials). These findings suggest that imitation-inhibition performance and difficulties in emotion regulation may be useful to predict autistic traits.

4. Discussion

Previous studies have provided mixed evidence for socio-cognitive deficits in individuals with autistic traits. Some studies propose a potential association between autism and impaired mirror neuron system (MNS; Williams et al., 2001) functioning, deficits in empathy (e.g., aan het Rot & Hogenelst, 2014), and challenges in social functioning.

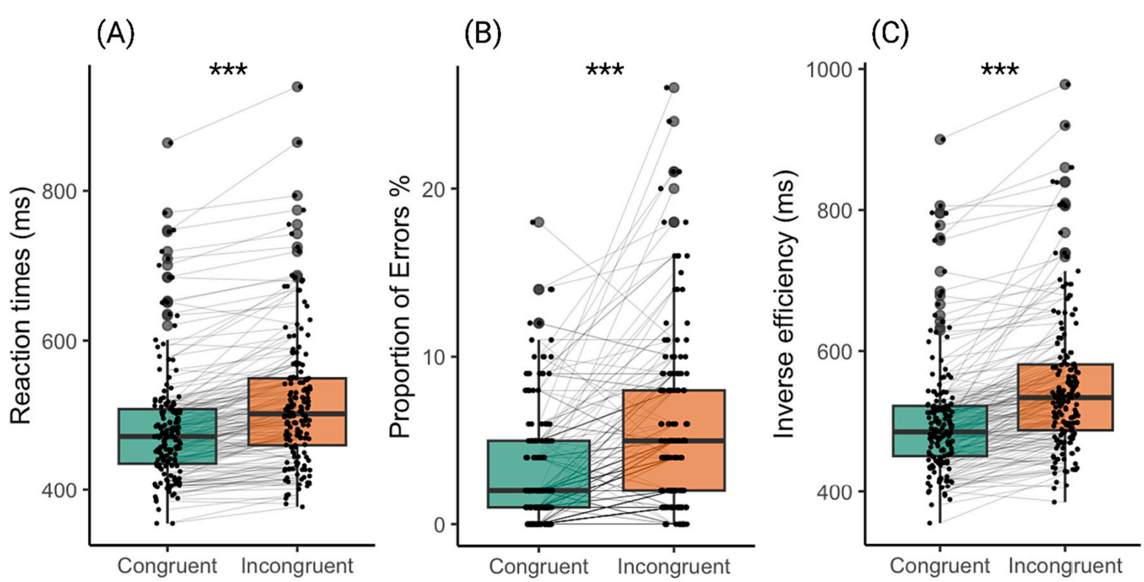

Fig. 2. Mean reaction times (A), proportion of errors (B) and inverse efficiency scores (C) as a function of congruency (Congruent and Incongruent conditions) of the imitation-inhibition paradigm. Each point represents a single participant, and the large dots represent outliers. The mean of the metric per participant in each condition is connected by a gray line. ***$p < 0.001$.

Table 1
Descriptive statistics and correlations between the applied psychometric measures.

Measure	*M*	*SD*	Range	1	2	3	4	5	6	7	8	9	10	11	12
1. Congruency IE	48.82	52.85	–	–											
2. Congruency RT	32.19	32.69	–	0.680 ***	–										
3. Congruency PE	0.03	0.04	–	0.509 ***	0.179 ***	–									
4. IRI FS	17.87	5.16	5–28	0.039	0.020	0.050	–								
5. IRI EC	19.98	4.56	4–28	0.085	0.096	0.029	0.283 ***	–							
6. IRI PT	19.61	3.98	8–27	−0.063	−0.056	−0.038	0.052	0.164 **	–						
7. IRI PD	13.01	5.27	0–25	0.004	0.043	−0.043	0.261 ***	0.132 *	−0.104	–					
8. DASS Stress	6.32	4.47	0–19	−0.016	0.034	−0.047	0.219 ***	0.026	−0.034	0.284 ***	–				
9. DASS Depression	4.86	4.76	0–20	−0.011	−0.017	0.047	0.180 **	−0.052	−0.082	0.144 **	0.557 ***	–			
10. DASS Anxiety	4.23	3.78	0–20	0.012	0.071	−0.043	0.151**	0.026	0.032	0.232 ***	0.676 ***	0.506 ***	–		
11. DERSE Total	57.27	18.12	27–115	0.062	0.091	0.018	0.319 ***	0.055	−0.104	0.470 ***	0.405 ***	0.402 ***	0.347 ***	–	
12. AQ-10	3.89	1.80	0–8	−0.124 *	−0.063	−0.170 **	0.039	−0.012	−0.010	0.133 *	0.132 *	0.082	0.101	0.162 **	–

Note. Correlation coefficients were computed with Kendall tau's rank correlations. *M*: mean; *SD*: standard deviation; Congruency IE: Inverse Efficiency; Congruency RT: Reaction Times; Congruency PE: Proportion of Errors; IRI: Interpersonal Reactivity Index; IRI FS: Fantasy; IRI EC: Empathic Concern; IRI PT: Perspective-Taking; IRI PD: Personal distress; DASS: Depression, Anxiety and Stress Scales; DERS: Difficulties in Emotion Regulation Scale; AQ-10: ten-item short form of the Autism-Spectrum Quotient; Range: the range of scores obtained *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

However, other studies have failed to replicate any MNS impairments (e.g., Southgate & Hamilton, 2008; Yates & Hobson, 2020) and have observed an absence of affective empathy and social issues in individuals with autism (Komeda et al., 2019; Santiesteban et al., 2021). This raises the fundamental question of the extent to which autistic traits are related to measures of social and affective cognition. In order to shed light on this question, we assessed autistic traits, empathy, and emotion regulation and then examined the associations among these measures. We found that imitation-inhibition abilities and emotion regulation difficulties are predictive of autistic traits, as measured by AQ-10 scores. However, empathy was not a statistically significant predictor of autistic traits. In the following section, we will discuss the present results, while highlighting their theoretical implications, limitations, and future directions.

4.1. Imitation-inhibition and autistic traits

The ability to inhibit imitation involves the capacity to differentiate and control representations of both the self and others, known as self-other distinction (SOD, Brass et al., 2009). Specifically, individuals need to suppress the motor representations activated by observed actions and enhance internally generated motor representations to prevent imitating another person's actions (Santiesteban, White et al., 2012). The SOD can be assessed via the congruency effect in the imitation-inhibition task. Thus, the lower the congruency effect, the better a participant distinguishes between self and other actions (Santiesteban, White et al., 2012). It has been suggested that impaired self-other monitoring processes in individuals with autism may result in deficits in their ability to inhibit imitation (Brass et al., 2009; Spengler et al., 2009). Contrary to our hypotheses, multiple regression analysis revealed that individuals with higher levels of autistic traits were associated with better imitation-inhibition performance (i.e., lower congruency effect IE scores). There are some possible explanations for this finding. First, a recent study by Gordon et al. (2020) found that individuals with more severe autistic traits had a smaller congruency effect in an imitation-inhibition task. The authors proposed that the enhanced imitation-inhibition observed in individuals with more severe autism may have been due to their increased focus on the numeric cue and decreased attention to the task-irrelevant stimulus (i.e., the hand). This suggestion is based on the evidence that greater autism symptom severity is linked to increased perseveration of attention (e.g., Sasson et al., 2008). Second, if autistic traits are related to problems in imitation-inhibition there is the possibility that people can develop compensatory strategies to deal with these difficulties. There is some evidence that individuals with autism might use executive function strategies to compensate for their socio-cognitive abilities difficulties (see Hull et al., 2020 for a review). In a previous study, females who were not diagnosed with autism until adulthood may have been able to avoid detection because of their strong ability to regulate and control their social behavior due to better executive functions (Lehnhardt et al., 2016). Future studies should aim at better disentangling the attentional and cognitive aspects of imitation-inhibition in order to understand why autistic traits can be advantageous to perform this task.

4.2. Emotion regulation and autistic traits

The current study also investigated the links between autistic traits and emotion regulation. Consistent with both our expectations and prior research (e.g., Mazefsky et al., 2013), we found that higher levels of autistic traits were associated with difficulties in emotion regulation. This finding seems at odds with our previous finding that higher levels of autistic traits are associated with better imitation-inhibition performance, implying that the SOD processes shared by emotion regulation and imitation-inhibition might be distinct from each other. This idea is supported by research showing that SOD processes for motor, affective and socio-cognitive domains may be entirely or partially distinct (Bukowski et al., 2021). The distinction between distinct SOD processes is further illustrated by the fact that demands for SOD vary across social abilities (Cook, 2014). For example, successful performance in theory of mind (ToM) tasks require enhancement of representations of the other and inhibiting self-representations (Brass et al., 2009). Conversely, imitation-inhibition requires enhancing self-representations and inhibiting the other. This allows participants to carry out the instructions dictated by the number without interference from the stimulus hand, which represents the other (Santiesteban, White et al., 2012). Therefore, as previous research has found, the control of SOD processes can be moderated by task demands (Cook, 2014). Interestingly, the results of the present study, along with previous findings that individuals with autism have impairments in ToM, suggest that autistic traits are related to the ability to enhance representations of the self but might have difficulties when the opposite is required, that is, enhancing representations of the other. In sum, while better imitation-inhibition in people with higher autistic traits may imply effective cognitive strategies to distinguish between their own actions and those of others, these people can still present deficits in emotion regulation because of an impaired SOD at the socio-cognitive level.

4.3. Empathy and autistic traits

There is some evidence suggesting that individuals with autism have deficits in affective empathy—the ability to share and understand the emotions of others— which can lead to difficulties in expressing and experiencing a full range of emotions and increased personal distress (Smith, 2009). This "lack of empathy" might stem from difficulties in comprehending and navigating social interactions, as well as an increased sensitivity to sensory stimuli. Contrary to this notion and against our initial expectations, our study found that empathy did not predict autistic traits. This finding aligns with a recent study that indicated individuals with autism do not inherently lack empathy (Santiesteban et al., 2021). Instead, autistic adults are able to experience the emotions of others but may find it more challenging to identify the emotions of others when asked to do so retrospectively (compared to non-autistic controls). In addition, it might be that the statistically significant relationship between autistic traits and empathy was not detected due to the differences between the measures. The Interpersonal Reactivity Index (IRI) is a self-report measure that is prone to demand characteristics such as the social desirability effect (e.g., Sassenrath, 2020). Since we tested non-autism participants rather than a sample diagnosed with autism it is possible that the demand characteristics inherent in self-report measures have played a role in these findings. It has been also suggested that a correlational approach is not effective for studying the role of self-other processes in empathy and that experimental approaches might be more suitable instead (Cracco et al., 2018). Further research using different measures of empathy and more comprehensive models may be necessary to better understand the relationship between empathy and autistic traits.

4.4. Theoretical implications

In this study, while we did not directly test the broken mirror theory of autism (Williams et al., 2001), the observed automatic tendency to imitate others, resulting in faster responses during congruent trials compared to incongruent trials in the imitation-inhibition paradigm, provides support for the idea that mirroring-associated mechanisms remain preserved in individuals with autistic traits. Therefore, in line with current research (e.g., Yates & Hobson, 2020) our results did not support the broken mirror theory of autism (Williams et al., 2001), suggesting that autism is not associated with MNS atypicalities. In contrast, our study provides partial support for the self-other control theory (Brass et al., 2009), which proposes that individuals with autism exhibit impaired abilities in controlling processes that distinguish self from other. Specifically, drawing from our results, one might posit that individuals with high autistic traits maintain unaffected SOD processes in the motor domain while experiencing impaired SOD in the affective and socio-cognitive domains. Future research is warranted to elucidate the specific SOD processes that are impaired in autism.

4.5. Limitations

A number of limitations need to be noted regarding the present study. One limitation is that the sample consisted of neurotypical adults without a current diagnosis of autism spectrum disorder (ASD). This may have limited the generalizability of our findings to individuals with ASD. Another limitation is that in the present study we utilized the AQ-10 as a measure to assess autistic traits, focusing primarily on the social dimension of these traits. While the AQ-10 offers a concise assessment, we acknowledge that it may not fully capture the breadth and complexity of autistic traits across other domains. It is important to note that this instrument has shown some weaknesses in previous studies (see Taylor et al., 2020), and, as a result, we must interpret our findings with caution, taking this limitation into account. Furthermore, despite implementing comprehensive inclusion/exclusion criteria during participant selection, we acknowledge that other co-occurring conditions, such as attention deficit hyperactivity disorder (ADHD), might potentially influence the observed results (see Lundin et al., 2019). Another limitation is that our study relied on self-report measures to assess empathy and difficulties in emotion regulation, which are subjective and may be influenced by factors such as social desirability. Using objective measures, such as real-life emotional scenarios (e.g., CARER Task; Santiesteban et al., 2021), may have provided more accurate results. Finally, our study only examined the relationship between empathy and autism in a cross-sectional design, so we were unable to determine the causal relationship between these variables. Therefore, employing alternative methods, such as non-invasive brain stimulation techniques like transcranial direct current stimulation (tDCS) and transcranial magnetic stimulation (TMS), could aid researchers in establishing causal inferences regarding socio-cognitive processes (e.g., Hogeveen et al., 2015; Santiesteban, Banissy et al., 2012).

5. Conclusion

The present study provides novel insights into the relationship between socio-cognitive processes and autistic traits in neurotypical adults. We found that imitation-inhibition and emotion regulation may be useful in predicting autistic traits, but empathy was not found to be a significant predictor. Interestingly, a negative relationship between imitation-inhibition and autistic traits was observed, meaning that those with better imitation-inhibition performance have higher autistic traits. Future studies should prioritize the enhancement of measurement techniques for socio-cognitive processes to more effectively disentangle their role in predicting autistic traits.

Declaration of competing interest

The authors declare that they have no conflict of interest.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.actpsy.2023.104056.

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